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Performance of Dual-Outrigger Structural System in Geometrically Irregular Shaped High-Rise Building

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Abstract*— The evolution of tall building has been enlarging worldwide and brings up various challenges. When building height increases, the stiffness of the structure largely reduces. For lateral load resisting outrigger system is very much effective to control the lateral Drift. Thus, to boost the performance of the structure under various lateral loading such as in wind or earthquake outrigger structural system plays very efficient role. In present paper an investigation has been focused on performance of dual outrigger structural system in geometrically irregular shaped building. Static and dynamic behavior of 60 storey irregular shaped building with different outrigger configurations was analysed by using ETABS Software. Wind analysis and Response spectrum method was carried out. The Parameters discussed in this paper include Storey Displacement, Storey Drift, Base shear, Base moment, Time period and Torsion for static and dynamic behaviour of different outrigger configurations.

***Keywords*— Outrigger, Belt truss, Response Spectrum Method, Geometry irregularity, High-Rise Building.**

I. INTRODUCTION

Nowadays tall buildings become taller and higher due to less availability of space in metro cities due to increasing population. Due to lesser space and higher land rates high rise building is the only feasible solution to accommodate the demands of developing cities.

But in India various developed cities lie in seismically active regions. Effect of lateral forces such as wind and earthquake become more crucial in design of high-rise frames due to its higher heights. Hence special systems shall be developed for resisting such lateral forces in addition to gravity loads in tall buildings. After study it is observed that there are various lateral load resisting structural systems are employed for designing the high-rise building projects.

A. Outrigger Structural System

In lateral load resisting structural system outrigger system works efficiently for lateral forces. Basically, in outrigger structural system, central core wall of structure and peripheral columns are connected with a rigid beam which is either in form of deep RCC beam or steel truss. Often in a building there could be some architectural constraints and it is difficult to provide outrigger beam which might obstruct the planning at that time it will be suitable to provide belt truss instead of conventional outriggers

Belt truss is basically a rigid RCC beam or Steel truss which connects all the peripheral columns so as to engage them in unison to resist lateral movements. This lateral load resisting system is used to control excessive story drift due to lateral loads generated either by wind or earthquake.

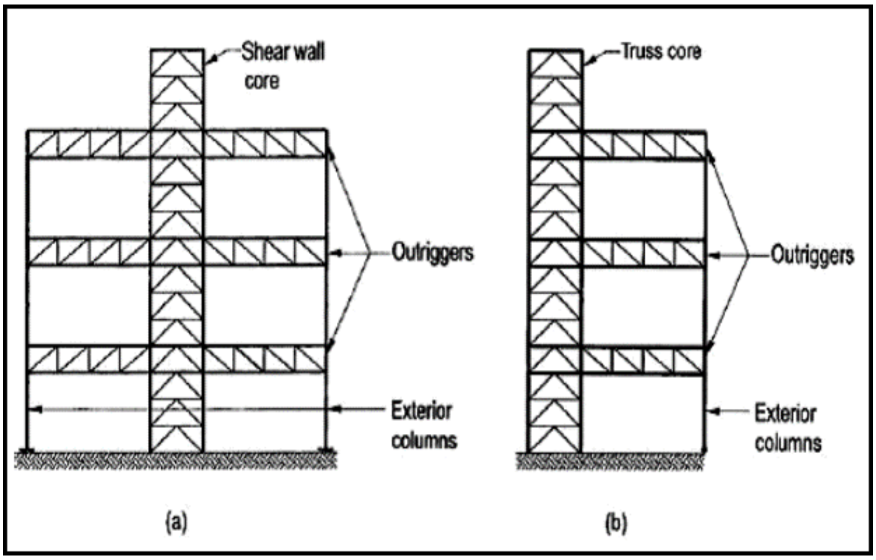


Fig. 1. OUTRIGGER STRUCTURAL SYSTEM

B. Concept of Outrigger

C.

The outrigger concept was originally derived from sailing canoe which runs on wind pressure during its journey in sea. Sometimes even in the high storm these sailing ship withstand to its position. Similarly, tall building can withstand to high lateral load by introducing outrigger in structure.

If we compare the element of sailing ship and building then Central core wall of building behave like a vertical mast of the sailing ship. And outrigger beam or truss is act like a spreader. Similarly, peripheral columns are representing the shrouds of sailing ship. This phenomenon has a great potential to be employed in tall buildings.

D. Behaviour of Outrigger

. The provision of outrigger structural system comprises of central core wall (i.e. lift shear wall) connected to the peripheral columns by single or double storey deep beam in case of RCC structure or sometime steel truss of that particular storey height is provided. This deep beam or steel truss is commonly referred as outrigger.

The working principle of outrigger structural system is very simple. When lateral loading either wind or earthquake load applied on the structure the rotation of central core wall is reduced due to the originating of axial forces in peripheral columns. Specifically, Tensile force is developed in windward columns and similarly compressive force will develop in leeward columns.

The result is the bending moment at a specific location where outrigger beam is provided is drastically reduced. As shown in fig. 2. For restraining the rotation of outriggers peripheral columns are also connected.

This can be possible by connecting the all peripheral columns with steel truss which is generally referred as belt truss or sometime single or double storey deep wall around the structure. Sometime it referred as “belt wall”.

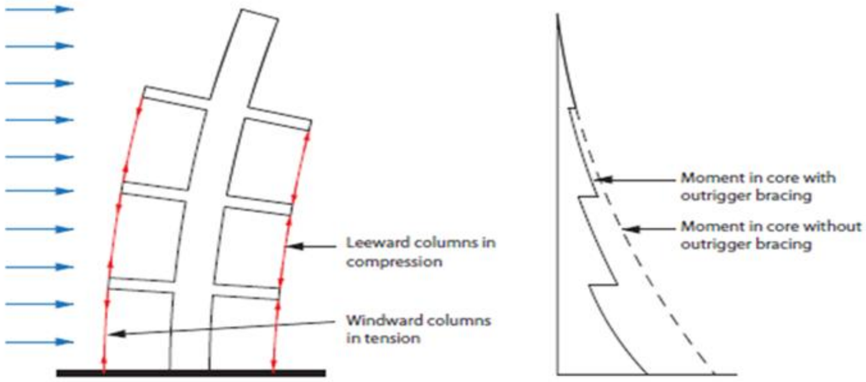


Fig. 2. BEHAVIOUR OF OUTRIGGER

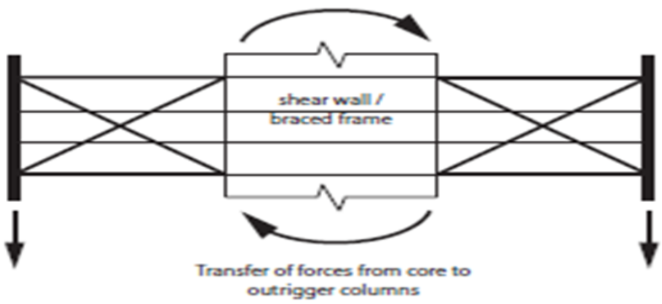


Fig. 3. BEHAVIOUR OF OUTRIGGER

II. OBJECTIVE OF RESEARCH

1) Finite Element models of reinforced concrete multi-storeyed building prototypes with G+60 storey geometrically irregular and unsymmetrical L shaped plan layouts with different outrigger configurations are modelled in ETABS.
2) To perform Static analysis of Geometrically irregular L shaped building models for earthquake analysis as per IS 1893 (Part 1) 2002.
3) To perform Dynamic analysis of geometrically irregular L shaped building models by response spectrum method using software ETABS. Furthermore, Dynamic analysis for earthquake assessment shall be performed by response spectrum method.
4) To determine the optimum location of belt-truss and outriggers arrangement by comparison of results for static and dynamic actions.
5) To perform a parametric study which include Storey Displacement, Storey Drift, Base Shear, Base Moment, Time Period and Torsion.

III. MODELS CONSIDERED FOR ANALYSIS

In current study, three-dimensional G+60 storied building with plan dimension 108.5 m x 106m are modelled (Fig 4). The typical floor height is 3.5m giving a total height of 214m. The beams, columns and shear walls are modelled as RC elements and outrigger is modelled as structural steel truss. Column and beam sizes considered in the analysis are 1200mm x 1200mm and 600mm x 800mm respectively.

A total 9 Different outrigger configurations by varying the position has been modelled and analysed.

1)	M1	Without outrigger
2)	M2	Outrigger at top
3)	M3	Outrigger at top and 0.4 H
4)	M4	Outrigger at top and 0.45 H
5)	M5	Outrigger at top and 0.5 H
6)	M6	Outrigger at top and 0.55 H
7)	M7	Outrigger at top and 0.6 H
8)	M8	Outrigger at top and 0.65 H
9)	M9	Outrigger at top and 0.7 H

Where, H is the height of building

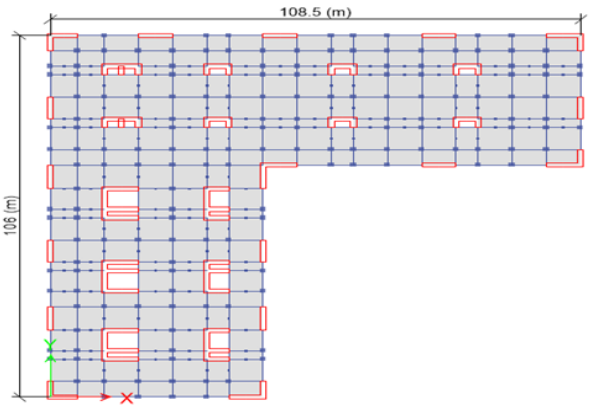


Fig. 4. TYPICAL PLAN OF BUILDING

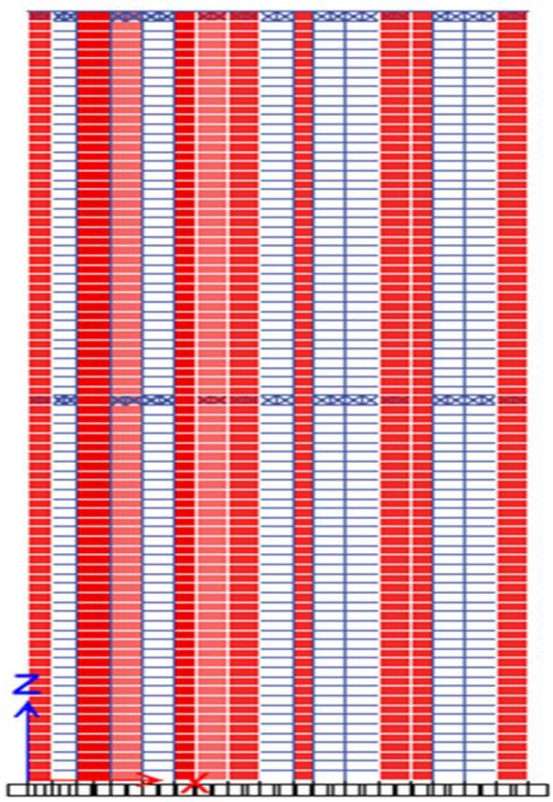


Fig. 5. ELEVATION (MODEL NO 5- OUTRIGGER AT TOP & 0.5H i.e. HEIGHT OF BUILDING)

The assumptions behind modelling this system are that the connection between shear wall core and foundation is rigid. The outrigger truss is rigidly connected to the stiff core on one side and simply supported on the peripheral column other side. Simple support condition is achieved through releasing major and minor moments (M33 & M22) of truss element at the peripheral column junction such that bending moments are not transferred and only axial thrust is exerted to the columns. The columns are sized and shall be designed such that it can safely carry the extra axial force (weather compression or tension) caused due to outriggers. The material behavior for analysis is considered to be linearly elastic. The outrigger trusses are kept very stiff so as to act as a rigid arm to transfer moments of core to the external column with minimum loss of forces due to distortion and flexure of outrigger itself.

IV. Load Consideration & Analysis Of The Frame

Equivalent static analysis method as per IS code is employed for assessing the static behavior of the models. Response spectrum and Wind analysis methods are employed to assess the linear dynamic behavior of the models. Basic wind speed is selected from wind data of Mumbai region.

Finite element software ETABS is used to carry out the above-mentioned analysis. In ETABS, shear walls and slabs are modelled as four nodded thin shell elements with default auto meshing. Beams, columns and truss elements are modelled as two nodded line elements. In addition, the truss members are released for moments on both of its ends to get exclusive axial brace behavior. Semi rigid diaphragm is assigned to all the floor elements to engage all columns in resisting lateral forces.

Loading:

- For slabs, of 1.5kN/m^2 floor finish load and 4kN/ m^2 of live load is considered as per IS-875 part 2 for commercial buildings.
- For beams, uniform load of 6kN/ m load is considered for partition walls made up of light weight blocks.
- From IS 1893 (PART-1) 2002 seismic load is considered. The following parameters have been considered for seismic analysis-

  Seismic Zone = Zone III (Z= 0.16)
  Importance Factor = 1.0
  Type of Soil = Medium Soil (Soil Type II)
  Response Reduction Factor = 4
  Damping Ratio = 5%
  Wind speed = 44 m/s
  Diaphragm = Semi Rigid

As per IS: 875 (part 5), load combinations are considered and structure is analysed

1.5(DL + LL)
1.2(DL + LL + EQX)
1.2(DL + LL - EQX)
1.2(DL + LL + EQY)
1.2(DL + LL - EQY)
1.5(DL+ EQX)
1.5(DL - EQX)
1.5(DL+ EQY)
1.5(DL - EQY)
0.9DL + 1.5EQX
0.9DL - 1.5EQX
0.9DL + 1.5EQY
0.9DL - 1.5EQY

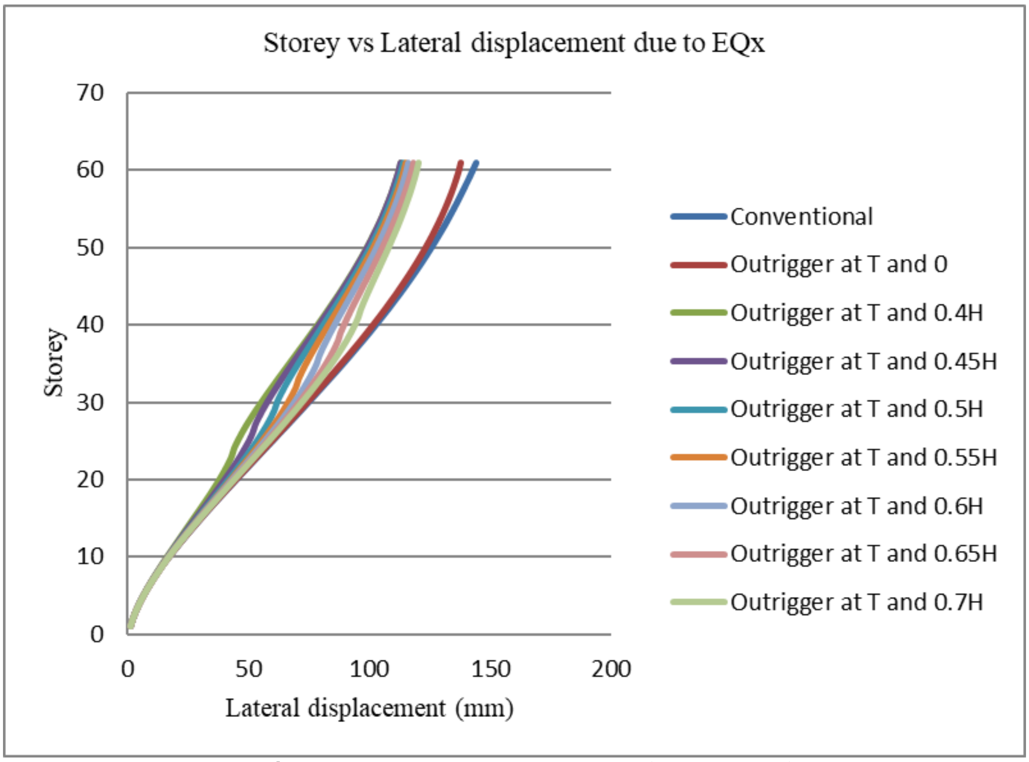
V. Results And Discussions

G+60 storey building is studied and following parameters are discussed which includes variation of Storey Displacement, Storey Drift, Base shear, Base moment, Time period and Torsion for static and dynamic behaviour of different outrigger configurations.

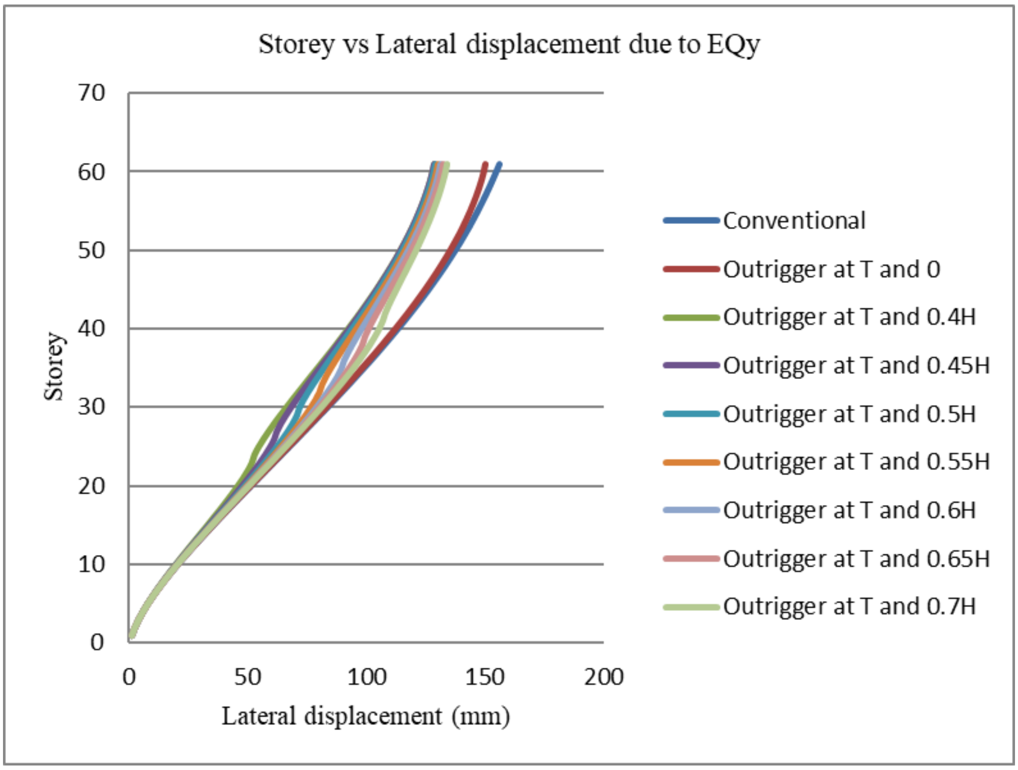
A. Storey Displacement

Graph 1 to 8 shows profiles for variation in storey displacement as well as graph 9 shows variation of top storey displacement in different outrigger configurations for equivalent static analysis, response spectrum analysis, wind analysis and gust factor analysis. From result obtained in Table no.1 maximum reduction is observed for M3 model where outrigger is provided at top and 0.4H i.e. height of the building. The percentage reduction in top storey displacement observed is as follow

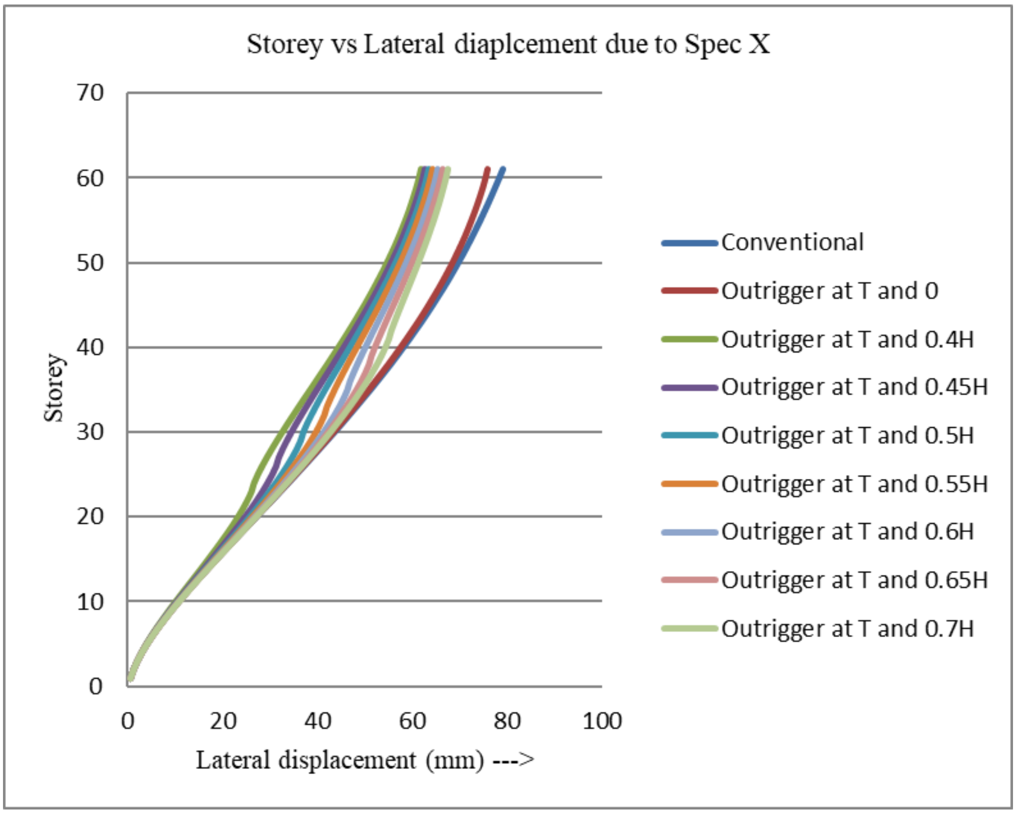
1. 21.83% in X-direction and 17.54% in Y-direction for Equivalent Static analysis.
2. 21.16% in X-direction and 17.56% in Y-direction for Response Spectrum analysis
3. 21.54% in X-direction and 17.66% in Y-direction for Wind analysis
4. 20.17% in X-direction and 23.81% in Y-direction for Gust Factor analysis



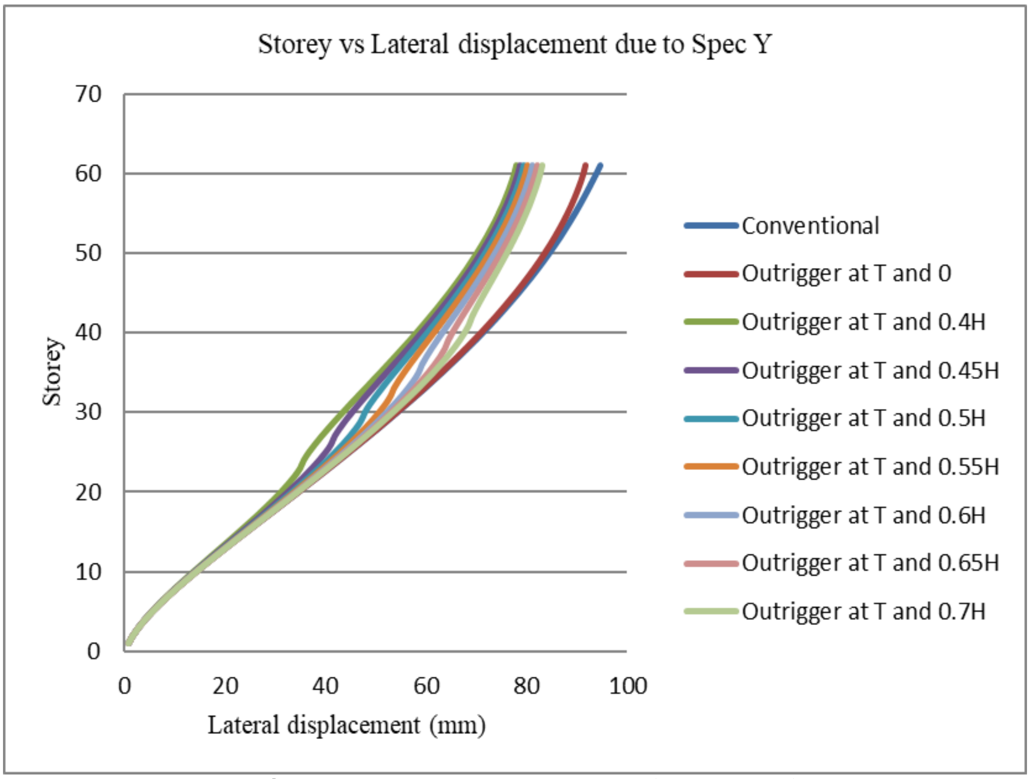
Graph 1. EQUIVALENT STATIC ANALYSIS (X DIRECTION)



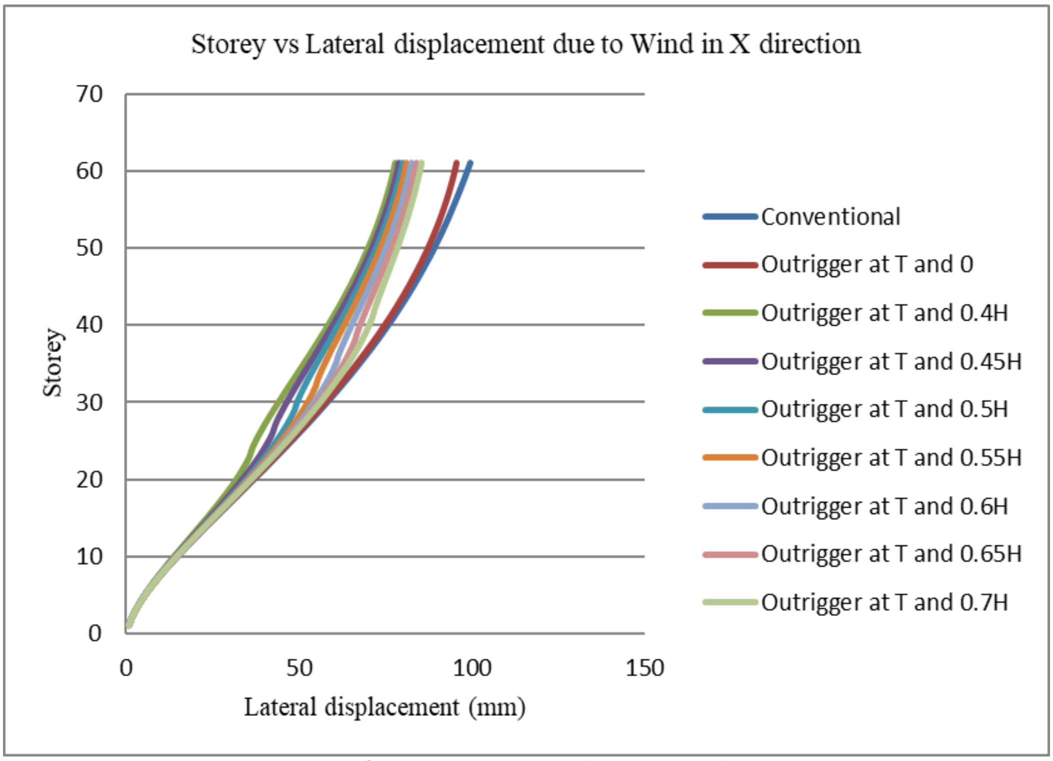
Graph 2. EQUIVALENT STATIC ANALYSIS (Y DIRECTION)



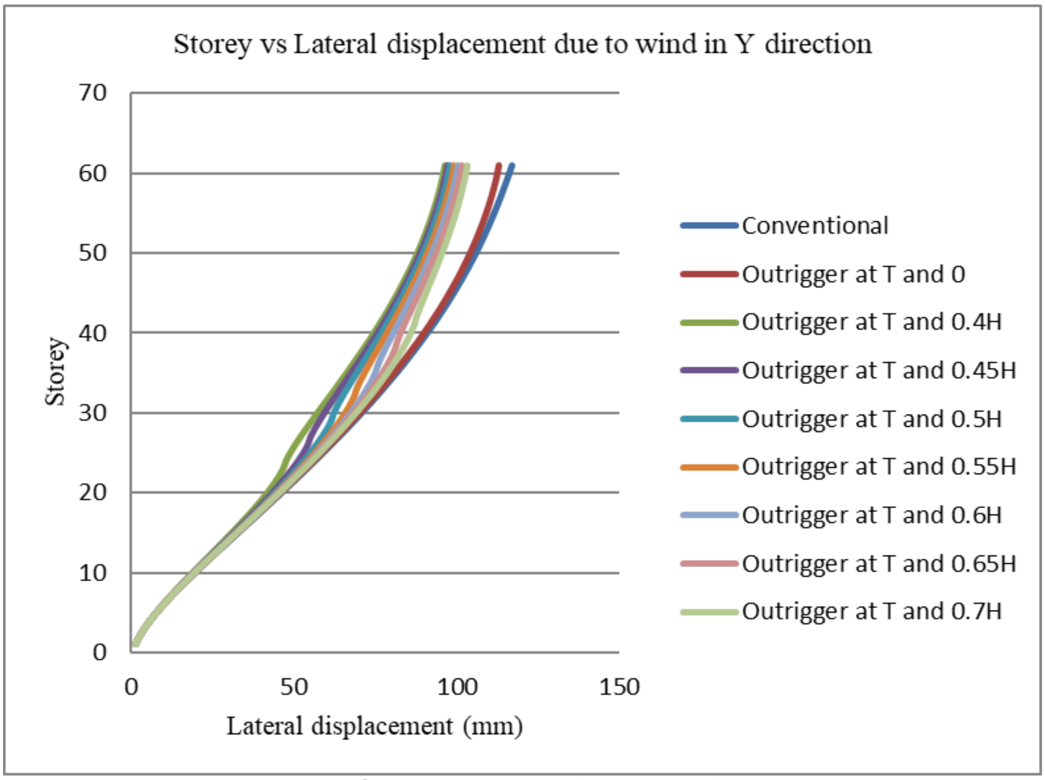
Graph 3. RESPONSE SPECTRUM ANALYSIS (X DIRECTION)



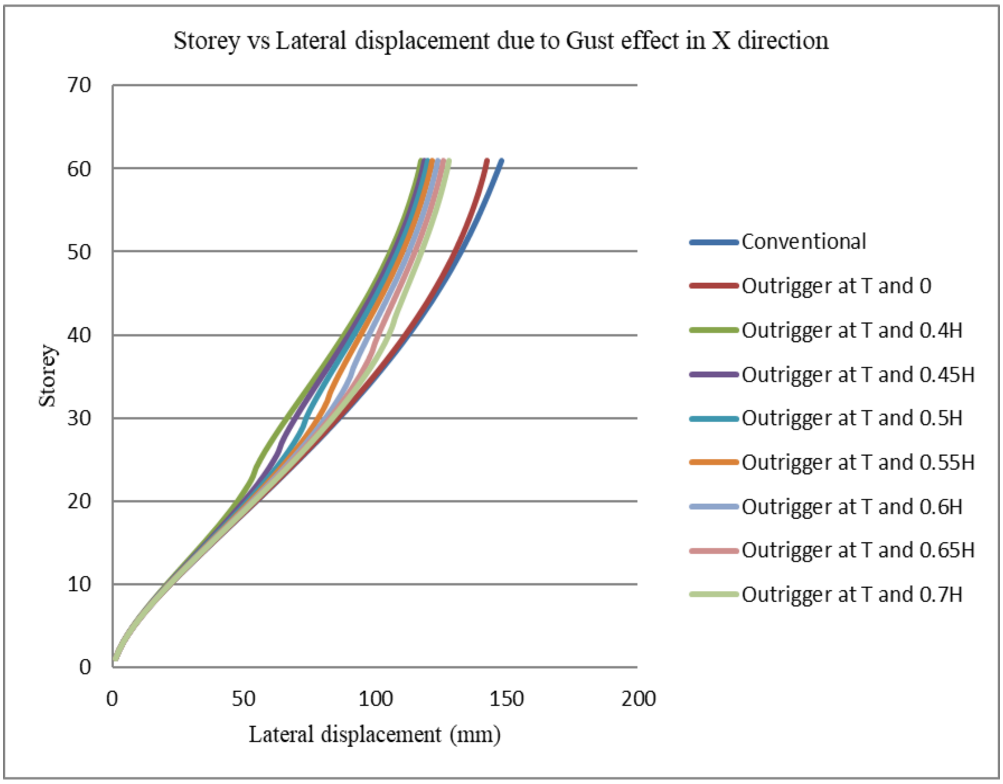
Graph 4. RESPONSE SPECTRUM ANALYSIS (Y DIRECTION)



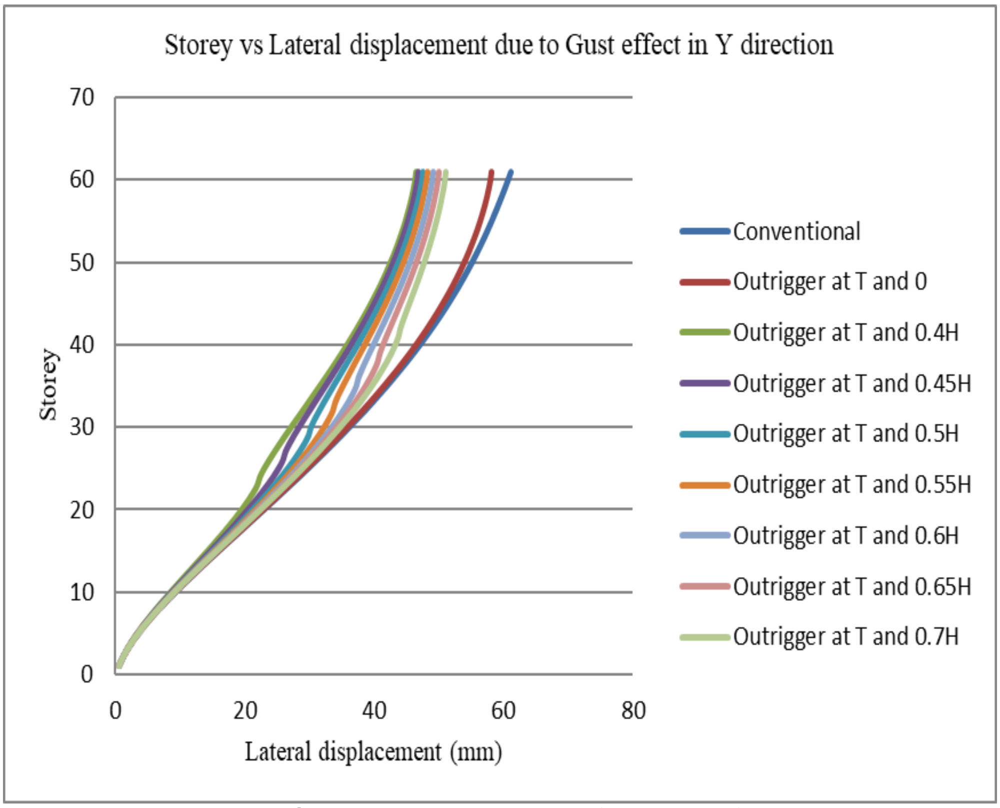
Graph 5. WIND ANALYSIS (X DIRECTION)



Graph 6. WIND ANALYSIS (Y DIRECTION)



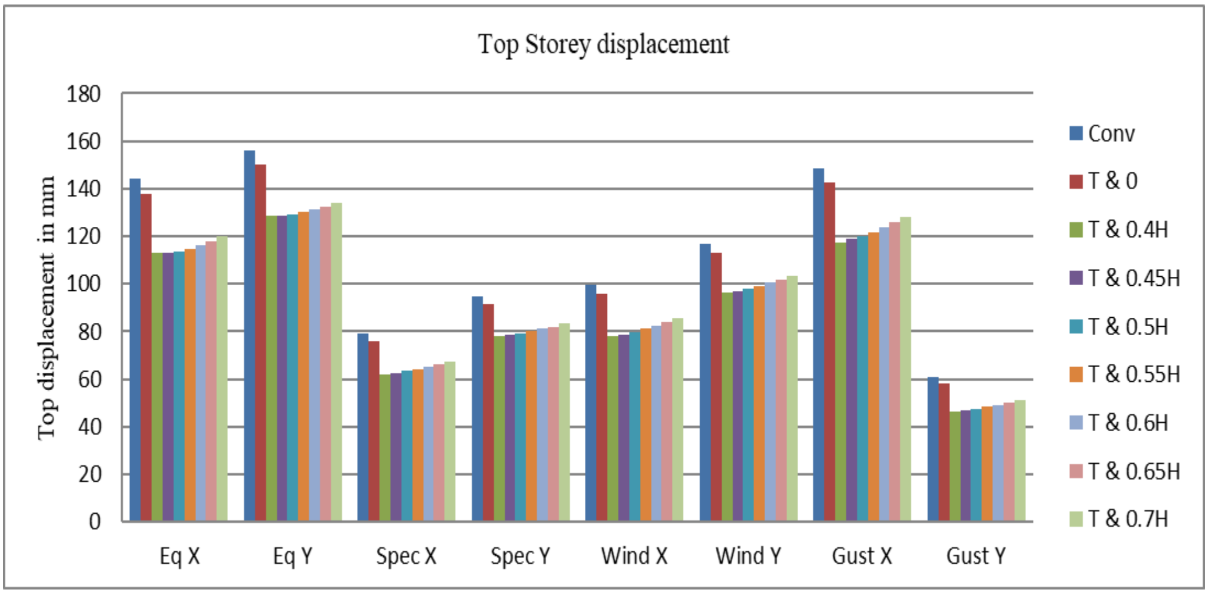
Graph 7. GUST FACTOR ANALYSIS (X DIRECTION)



Graph 8. GUST FACTOR ANALYSIS (Y DIRECTION)

TABLE -1: PERCENTAGE REDUCTION IN TOP STOREY DISPLACEMENT WITH DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS, WIND ANALYSIS AND GUST FACTOR ANALYSIS IN X AND Y DIRECTION)

Top Storey Displacement									
	Conv	T & 0	T & 0.4H	T & 0.45H	T & 0.5H	T & 0.55H	T & 0.6H	T & 0.65H	T & 0.7H
Eq X	144.269	137.834	112.78	113.025	113.708	114.784	116.22	117.996	120.091
Eq Y	155.998	150.102	128.631	128.788	129.28	130.079	131.168	132.535	134.172
Spec X	79.039	75.951	61.96	62.583	63.335	64.213	65.214	66.33	67.541
Spec Y	94.58	91.58	77.972	78.569	79.297	80.136	81.074	82.1	83.198
Wind X	99.407	95.629	77.993	78.823	79.898	81.152	82.535	84.013	85.556
Wind Y	116.88	113.097	96.24	97.033	98.022	99.156	100.399	101.724	103.11
Gust X	148.285	142.69	117.577	118.684	120.147	121.873	123.793	125.857	128.024
Gust Y	61.111	58.18	46.559	46.932	47.516	48.262	49.133	50.098	51.13
% Reduction in Top Storey Displacement	Eq X	4.46%	21.83%	21.66%	21.18%	20.44%	19.44%	18.21%	16.76%
	Eq Y	3.78%	17.54%	17.44%	17.13%	16.61%	15.92%	15.04%	13.99%
	Spec X	3.91%	21.61%	20.82%	19.87%	18.76%	17.49%	16.08%	14.55%
	Spec Y	3.17%	17.56%	16.93%	16.16%	15.27%	14.28%	13.20%	12.03%
	Wind X	3.80%	21.54%	20.71%	19.63%	18.36%	16.97%	15.49%	13.93%
	Wind Y	3.24%	17.66%	16.98%	16.13%	15.16%	14.10%	12.97%	11.78%
	Gust X	3.77%	20.71%	19.96%	18.98%	17.81%	16.52%	15.12%	13.66%
	Gust Y	4.80%	23.81%	23.20%	22.25%	21.03%	19.60%	18.02%	16.33%

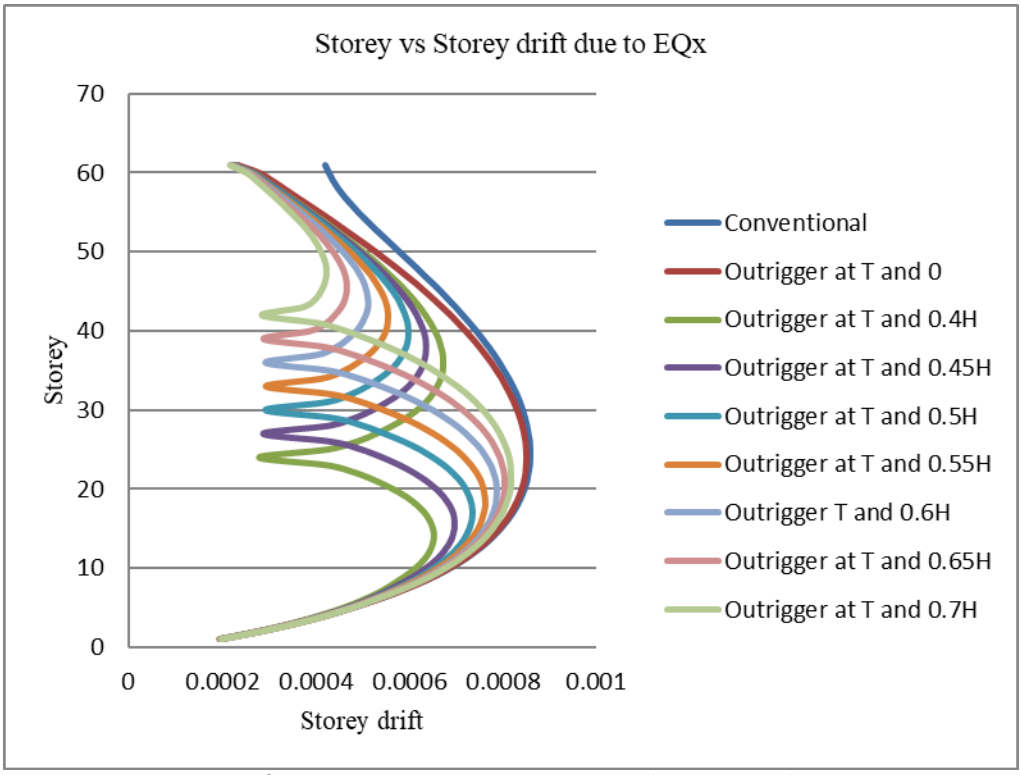


Graph 9. TOP STOREY DISPLACEMENT TOP STOREY DRIFT (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS, WIND ANALYSIS AND GUST FACTOR ANALYSIS IN X AND Y DIRECTION)

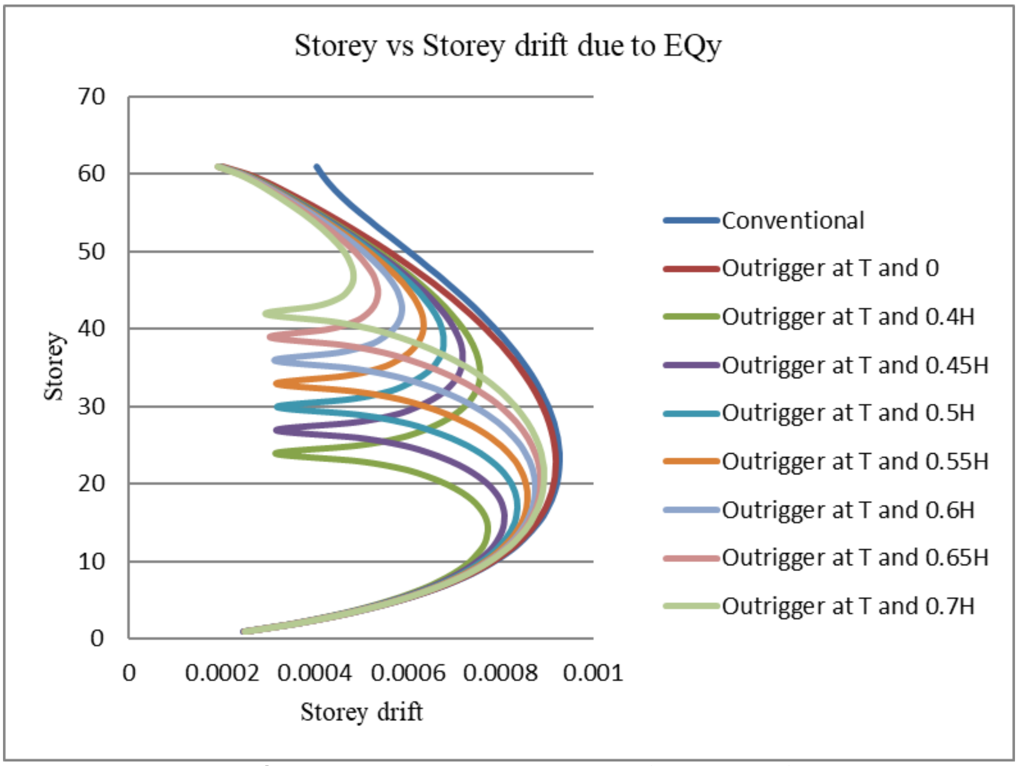
B. Storey Drift

Graph 10 to 17 shows profiles for variation in storey drift as well as graph 18 shows variation of maximum storey drift in different outrigger configurations for equivalent static analysis, response spectrum analysis, wind analysis and gust factor analysis. It can be observed from graphs in chart 10 to 15, the sudden change or drop in story drift is due to high stiffness in wall at those outrigger stories due to presence of stiff trussed which restricts rotation of walls. From result obtained in Table no.2 maximum percentage reduction in drift is observed for M3 model where outrigger is provided at top and 0.4H i.e. height of the building. The reduction in maximum storey drift observed is as follow

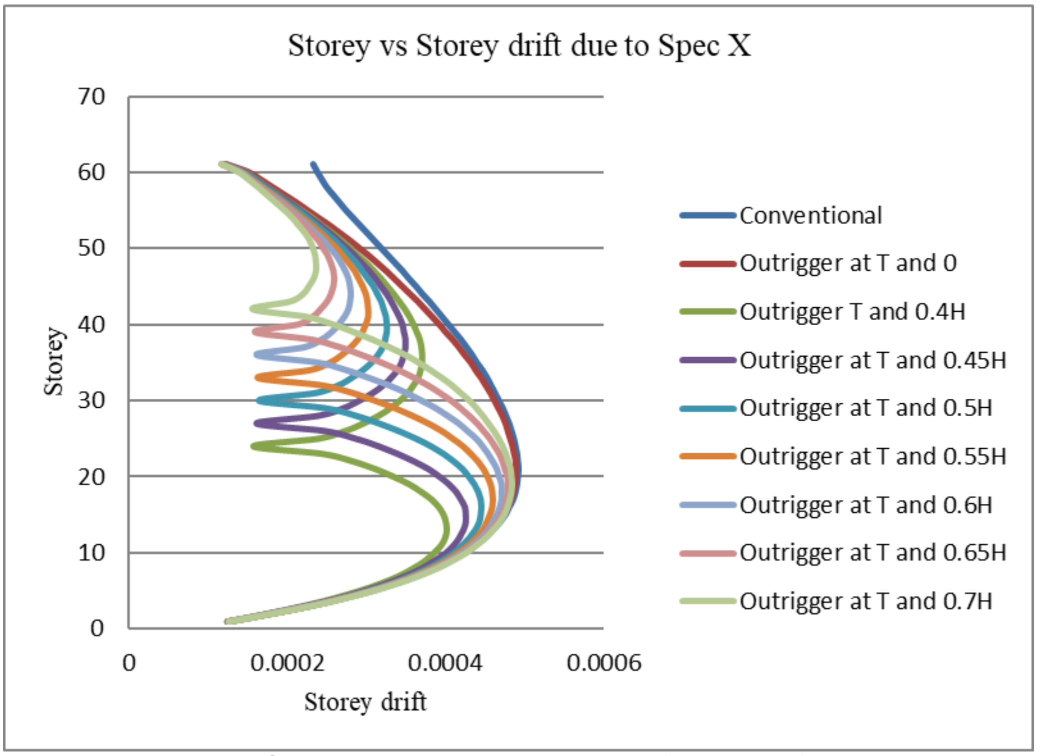
1. 21.51% in X-direction and 16.61% in Y-direction for Equivalent Static analysis.
2. 18.46% in X-direction and 11.73% in Y-direction for Response Spectrum analysis
3. 15.11% in X-direction and 9.65% in Y-direction for Wind analysis
4. 14.80% in X-direction and 17.34% in Y-direction for Gust Factor analysis



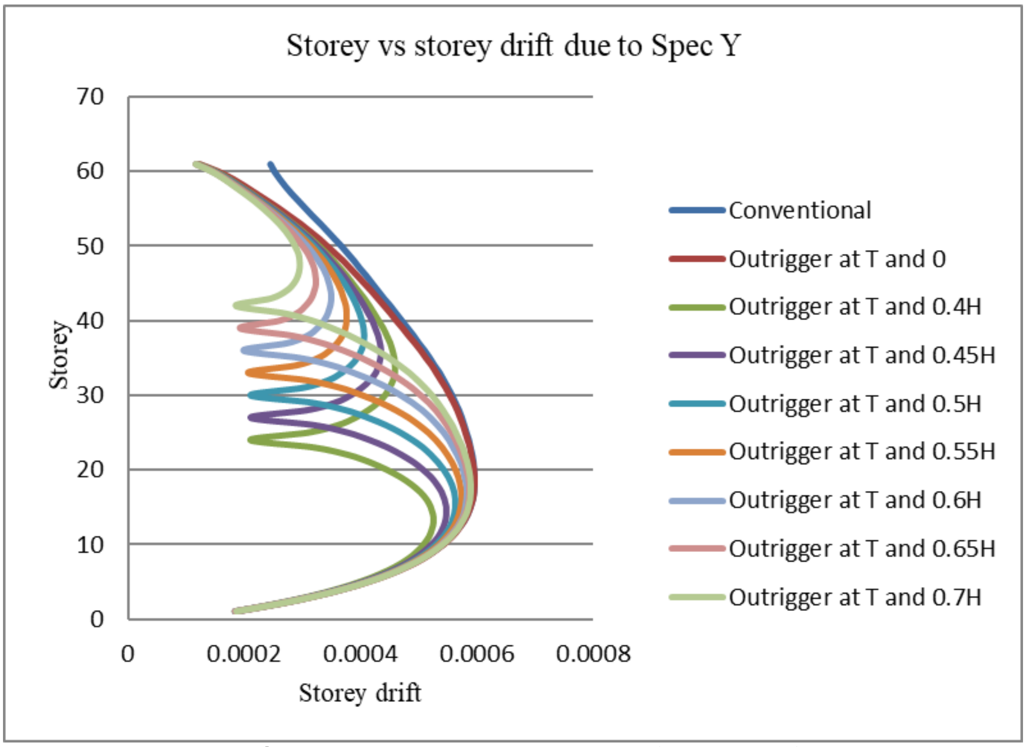
Graph 10. EQUIVALENT STATIC ANALYSIS (X DIRECTION)



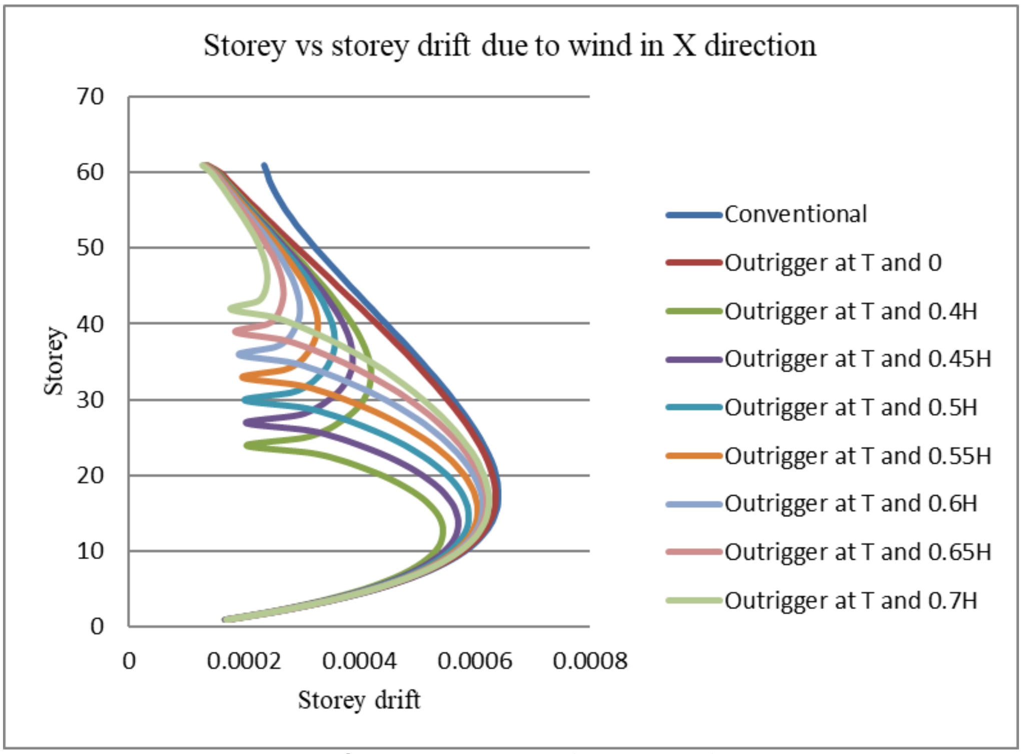
Graph 11. EQUIVALENT STATIC ANALYSIS (Y DIRECTION)



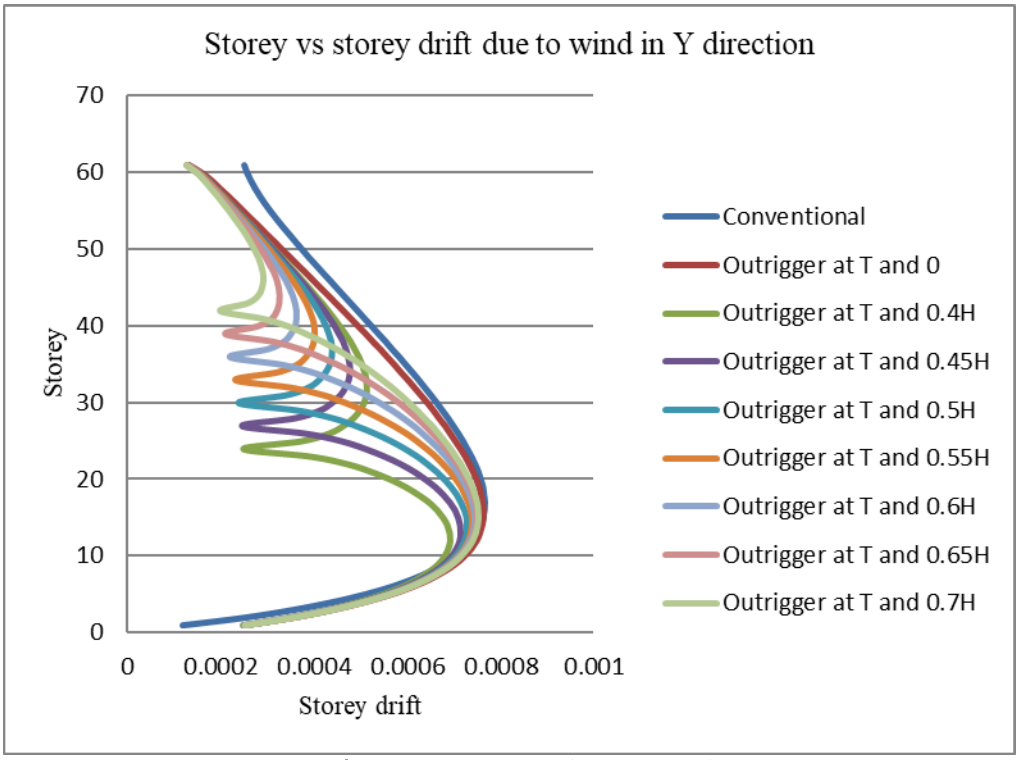
Graph 12. RESPONSE SPECTRUM ANALYSIS (X DIRECTION)



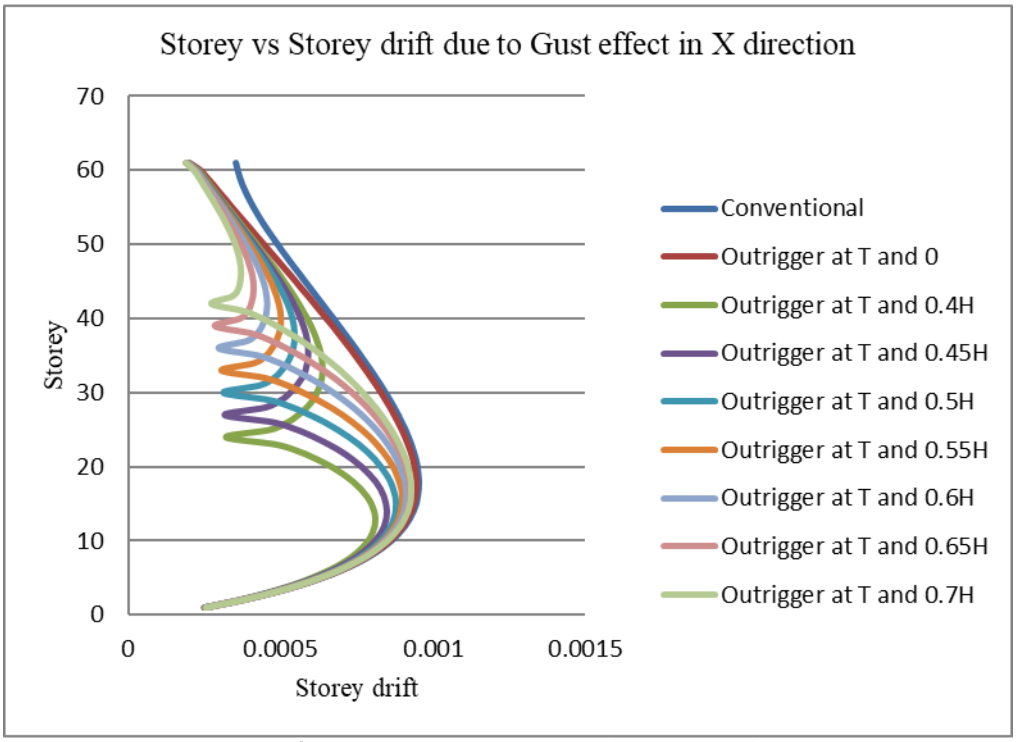
Graph 13. RESPONSE SPECTRUM ANALYSIS (Y DIRECTION)



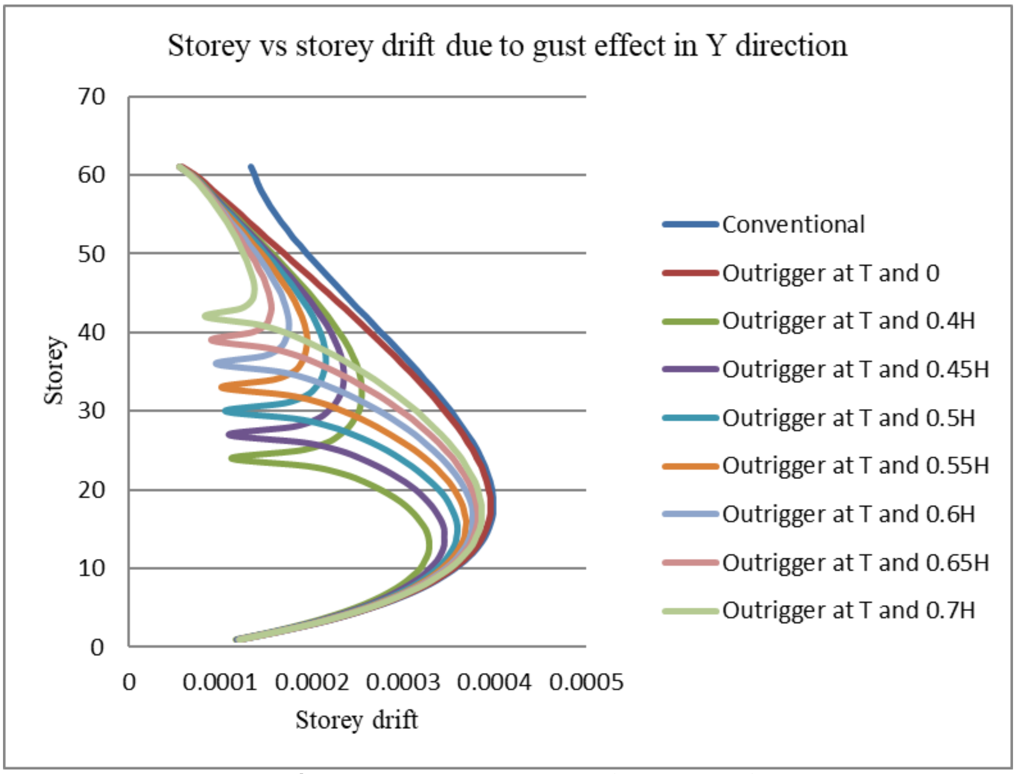
Graph 14. WIND ANALYSIS (X DIRECTION)



Graph 15. WIND ANALYSIS (Y DIRECTION)



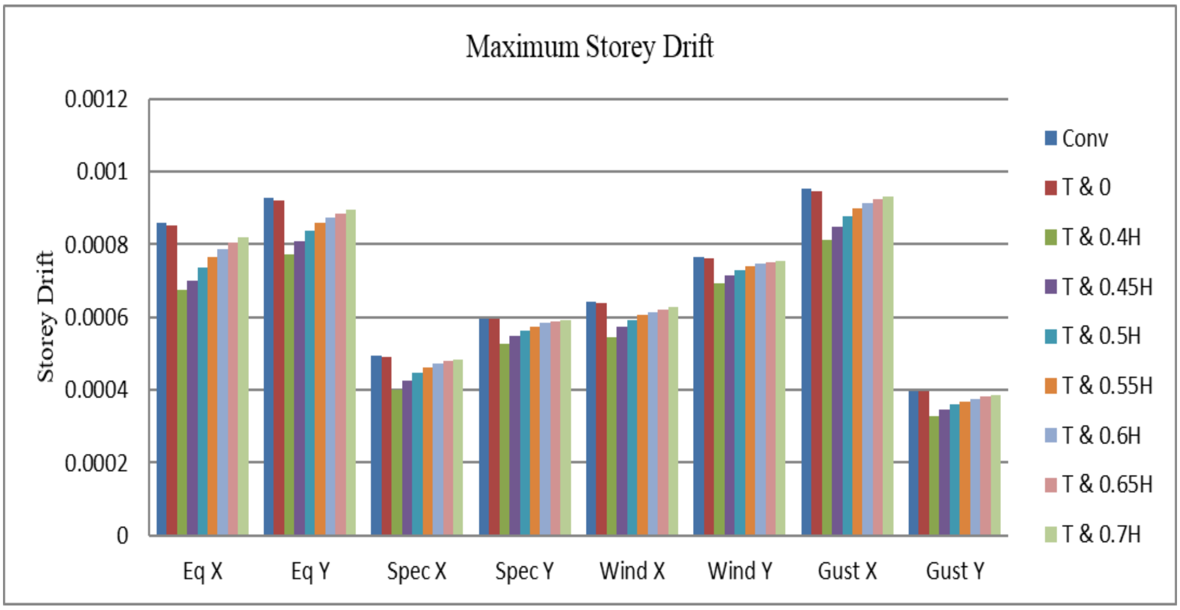
Graph 16. GUST FACTOR ANALYSIS (X DIRECTION)



Graph 17. GUST FACTOR ANALYSIS (Y DIRECTION)

TABLE -2: PERCENTAGE REDUCTION IN MAXIMUM STOREY DRIFT WITH DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS, WIND ANALYSIS AND GUST FACTOR ANALYSIS IN X AND Y DIRECTION)

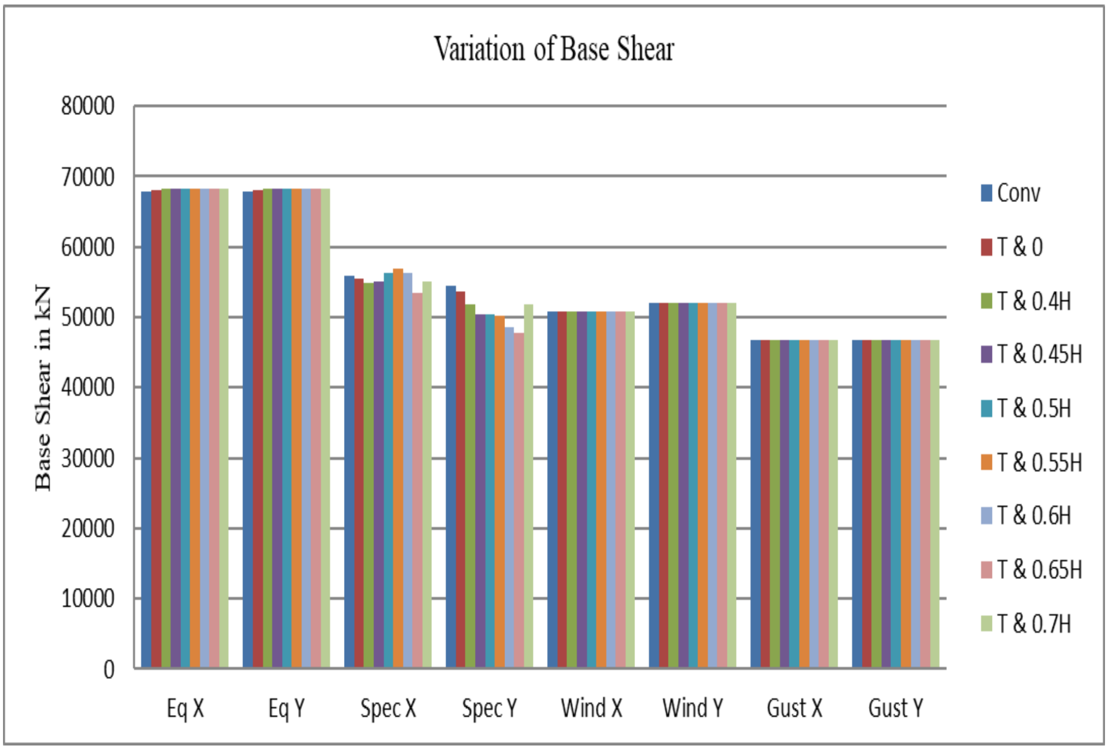
Maximum Storey Drift									
	Conv	T & 0	T & 0.4H	T & 0.45H	T & 0.5H	T & 0.55H	T & 0.6H	T & 0.65H	T & 0.7H
Eq X	0.00086	0.000851	0.000675	0.000699	0.000736	0.000765	0.000788	0.000805	0.000818
Eq Y	0.000927	0.00092	0.000773	0.000809	0.000837	0.000858	0.000874	0.000886	0.000895
Spec X	0.000493	0.00049	0.000402	0.000426	0.000446	0.000461	0.000471	0.000479	0.000484
Spec Y	0.000597	0.000596	0.000527	0.000547	0.000563	0.000575	0.000583	0.000588	0.000591
Wind X	0.000642	0.000638	0.000545	0.000572	0.000591	0.000605	0.000615	0.000622	0.000627
Wind Y	0.000767	0.000763	0.000693	0.000714	0.000729	0.000739	0.000746	0.000751	0.000754
Gust X	0.000953	0.000947	0.000812	0.00085	0.000878	0.000899	0.000913	0.000923	0.00093
Gust Y	0.000398	0.000396	0.000329	0.000345	0.000359	0.000369	0.000376	0.000382	0.000386
% Reduction in Maximum Storey Drift	Eq X	1.05%	21.51%	18.72%	14.42%	11.05%	8.37%	6.40%	4.88%
	Eq Y	0.76%	16.61%	12.73%	9.71%	7.44%	5.72%	4.42%	3.45%
	Spec X	0.61%	18.46%	13.59%	9.53%	6.49%	4.46%	2.84%	1.83%
	Spec Y	0.17%	11.73%	8.38%	5.70%	3.69%	2.35%	1.51%	1.01%
	Wind X	0.62%	15.11%	10.90%	7.94%	5.76%	4.21%	3.12%	2.34%
	Wind Y	0.52%	9.65%	6.91%	4.95%	3.65%	2.74%	2.09%	1.69%
	Gust X	0.63%	14.80%	10.81%	7.87%	5.67%	4.20%	3.15%	2.41%
	Gust Y	0.50%	17.34%	13.32%	9.80%	7.29%	5.53%	4.02%	3.02%



Graph 18. TOP STOREY DRIFT (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS, WIND ANALYSIS AND GUST FACTOR ANALYSIS IN X AND Y DIRECTION)

C. Base Shear

Graph 19 and table No.3 shows variation of base shear in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis, Wind analysis and Gust Factor analysis in X and Y Direction. And from Graph 19 it is observed that there is no significant variation of base shear values with provision of different outrigger configurations



Graph 19. BASE SHEAR GRAPH WITH DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS WIND ANALYSIS AND GUST FACTOR ANALYSIS - X & Y DIRECTION)

TABLE 3. BASE REACTIONS (IN KN) FOR DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS, WIND ANALYSIS AND GUST FACTOR ANALYSIS- X &Y DIRECTION)

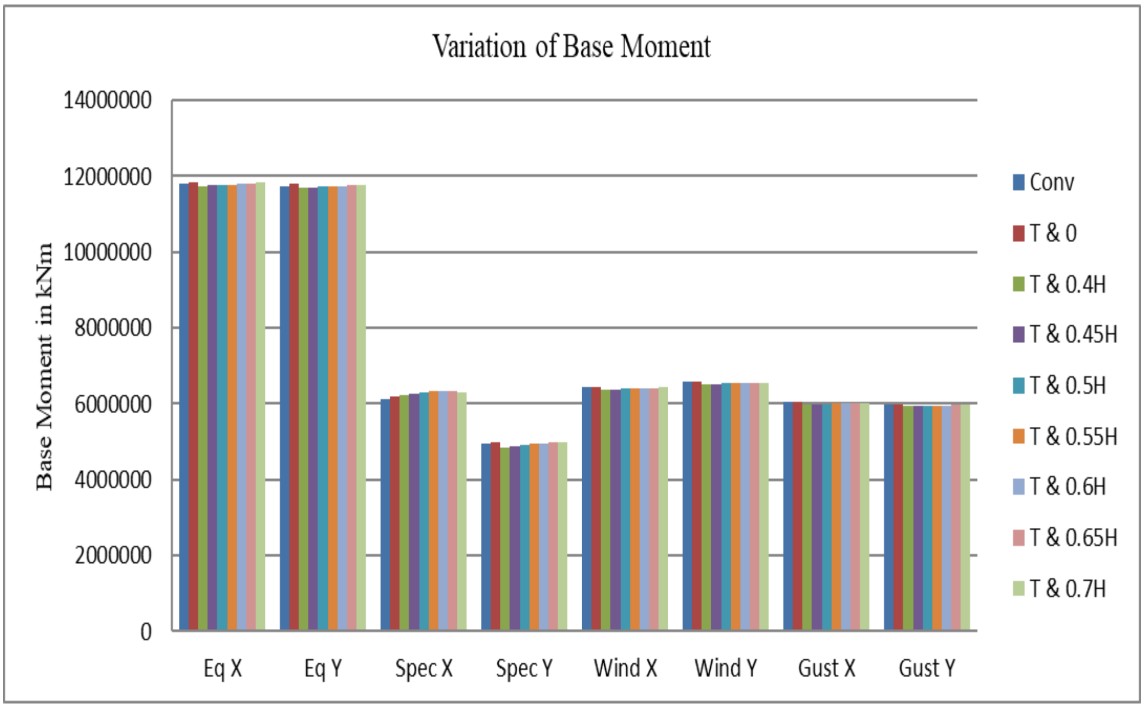
Base Shear									
	Conv kN	T & 0 kN	T & 0.4H kN	T & 0.45H kN	T & 0.5H kN	T & 0.55H kN	T & 0.6H kN	T & 0.65H kN	T & 0.7H kN
Eq X	67903	68084	68265	68265	68265	68265	68265	68265	68265
Eq Y	67903	68084	68265	68265	68265	68265	68265	68265	68265
Spec X	55816	55577	54773	55120	56388	56925	56210	53519	55066
Spec Y	54395	53671	51784	50467	50508	50110	48554	47674	51824
Wind X	50823	50823	50823	50823	50823	50823	50823	50823	50823
Wind Y	52022	52022	52022	52022	52022	52022	52022	52022	52022
Gust X	46670	46670	46670	46670	46670	46670	46670	46670	46670
Gust Y	46670	46670	46670	46670	46670	46670	46670	46670	46670

Above graphs indicate that, there is no significant difference in base shear values among different models due to addition of outriggers. Reason behind that is, the outrigger doesn't significantly increase the seismic weight of the building and as per the codal philosophies the seismic inertial forces are directly proportional to the weight of the building. So, no increase in weight results in no increase in base shears.

However, in case of response spectrum results few variations could be observed but they are due to the random nature of ground motions and its variable effect on various frames and floor stiffness.

D. Base Moments

Graph 20 and table No.4 shows variation of base moments in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis, Wind analysis and Gust Factor analysis in X and Y Direction. And from Graph 19 it is observed that there is no significant variation of base shear values with provision of different outrigger configurations.



Graph 20. BASE MOMENT GRAPH WITH DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS WIND ANALYSIS AND GUST FACTOR ANALYSIS - X & Y DIRECTION)

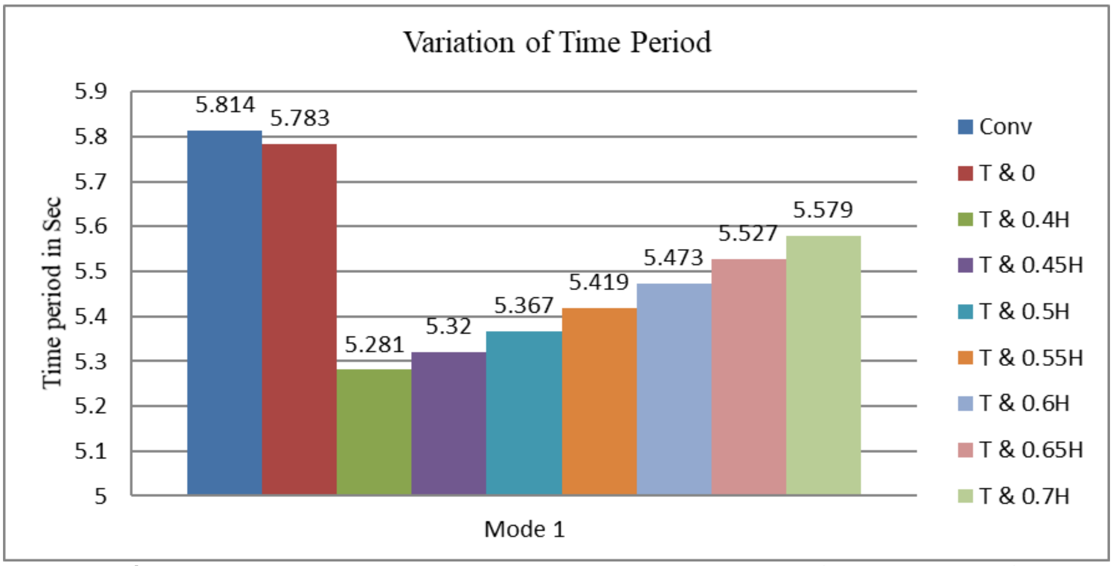
TABLE 4. **BASE MOMENT (IN KN) FOR DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS, WIND ANALYSIS AND GUST FACTOR ANALYSIS- X &Y DIRECTION)**

Base Moment									
	Conv kNm	T & 0 kNm	T & 0.4H kNm	T & 0.45H kNm	T & 0.5H kNm	T & 0.55H kNm	T & 0.6H kNm	T & 0.65H kNm	T & 0.7H kNm
Eq X	11801279	11852191	11739916	11751027	11764070	11778428	11793624	11809272	11825036
Eq Y	11746997	11796480	11700620	11708654	11718907	11730799	11743850	11757649	11771838
Spec X	6139421	6202300	6231979	6279984	6310794	6326073	6329978	6325524	6315873
Spec Y	4945086	4971534	4847551	4883712	4915172	4940453	4960239	4975729	4987442
Wind X	6457753	6454251	6379027	6388099	6397425	6406570	6415241	6423243	6430441
Wind Y	6593579	6589705	6522775	6529978	6537660	6545414	6552943	6560033	6566527
Gust X	6053113	6049180	5975298	5983862	5992788	6001630	6010083	6017937	6025046
Gust Y	5997213	5993611	5933700	5939796	5946470	5953325	5960063	5966465	5972368

The above graph is clearly indicating that there is no significant difference in base moment values for equivalent static analysis, wind analysis and gust factor analysis. But for Response spectrum analysis base moment value considerably decreases due to variable mass at different floors and Equivalent static analysis and Wind analysis methods fails to catch the same.

E. Time Period

Graph 21 and table No.5 shows graph for variation of time period in different outrigger configuration for modal analysis and it is found that there is maximum reduction in time period when outriggers are placed at top and 0.4H i.e. height of the structure.



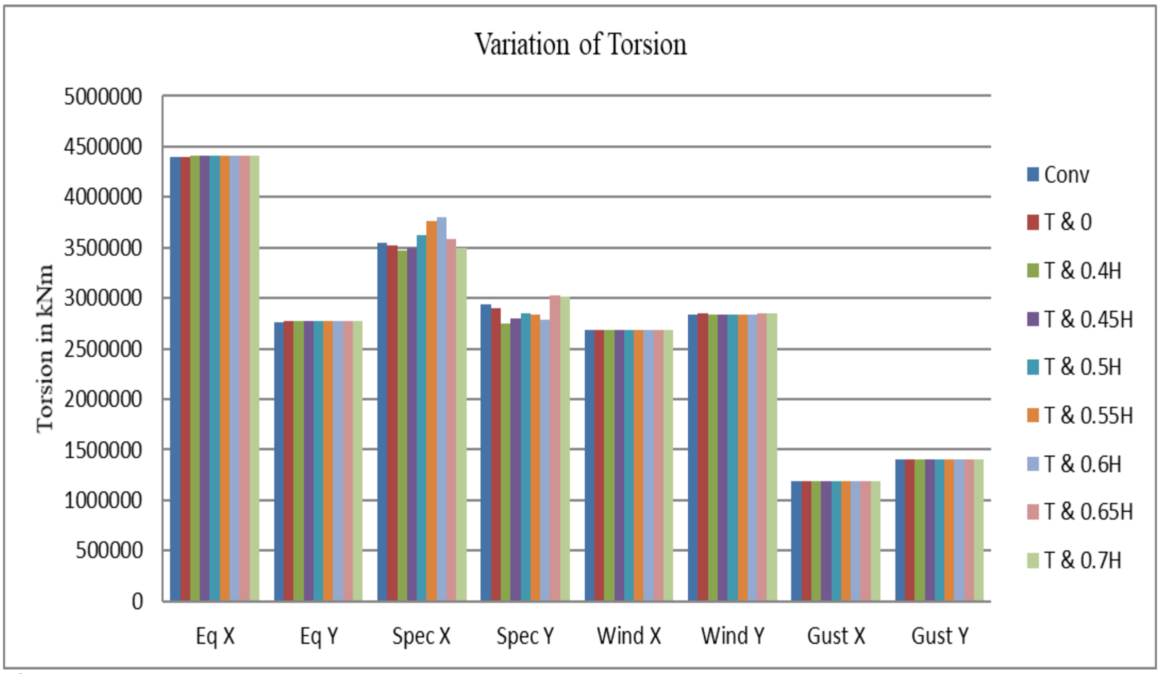
Graph 21. TIME PERIOD WITH DIFFERENT OUTRIGGER CONFIGURATION (MODAL ANALYSIS)

TABLE 5. PERCENTAGE REDUCTION IN TIME PERIOD WITH DIFFERENT OUTRIGGER CONFIGURATIONS (MODAL ANALYSIS)

Time Period									
	Conv	T & 0	T & 0.4H	T & 0.45H	T & 0.5H	T & 0.55H	T & 0.6H	T & 0.65H	T & 0.7H
Mode 1	5.814	5.783	5.281	5.32	5.367	5.419	5.473	5.527	5.579
% Reduction in time period	Mode 1	0.53%	9.17%	8.50%	7.69%	6.79%	5.87%	4.94%	4.04%

F. Torsion

Graph 22 and table No.6 shows variation of base moments in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis, Wind analysis and Gust Factor analysis in X and Y Direction. And from Graph 20 it is observed that there is no significant variation of torsion values with provision of different outrigger configurations.



Graph 22. TORSION GRAPH WITH DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS WIND ANALYSIS AND GUST FACTOR ANALYSIS - X & Y DIRECTION)

TABLE 6. **TORSION (IN KNM) FOR DIFFERENT OUTRIGGER CONFIGURATION (EQUIVALENT STATIC ANALYSIS, RESPONSE SPECTRUM ANALYSIS, WIND ANALYSIS AND GUST FACTOR ANALYSIS- X &Y DIRECTION)**

Torsion									
	Conv	T & 0	T & 0.4H	T & 0.45H	T & 0.5H	T & 0.55H	T & 0.6H	T & 0.65H	T & 0.7H
	kNm	kNm	kNm	kNm	kNm	kNm	kNm	kNm	kNm
Eq X	4389913	4401572	4414506	4414421	4414303	4414168	4414026	4413885	4413751
Eq Y	2761306	2768491	2775206	2775358	2775457	2775516	2775545	2775554	2775550
Spec X	3540727	3518740	3475856	3498772	3622078	3761980	3799277	3580246	3499066
Spec Y	2935504	2905697	2746375	2800552	2847137	2832832	2790739	3028599	3014955
Wind X	2681779	2681357	2683637	2683269	2682905	2682565	2682261	2681998	2681778
Wind Y	2842845	2843643	2841433	2841916	2842340	2842704	2843009	2843259	2843459
Gust X	1188943	1187602	1193195	1192214	1191268	1190399	1189632	1188977	1188436
Gust Y	1405656	1405530	1406609	1406468	1406306	1406142	1405986	1405849	1405734

VI. CONCLUSIONS

The focus of current study is seismic response of geometrically irregular shaped (in plan) structures and study of various parameters which include Storey displacement, Storey drift, Base reactions, Base moments, Time Period and Torsion by introducing outrigger structural system. For minimizing the twisting effect in tall irregular shaped building optimum location of outrigger play vital role, increases stiffness and performance of structure under lateral load.

Based on the above results obtained analyzing following conclusions are made:

1. In static and dynamic behaviour when we consider the storey displacement and storey drift parameters then the optimum location of outrigger is at top and 0.4H i.e. height of the building.
2. In parameter study of Storey Displacement it is reduced by 21.83% in X-direction and 17.54% in Y-direction for Equivalent Static analysis,21.61% in X-direction and 17.56% in Y-direction for Response Spectrum analysis, 21.54% in X-direction and 17.66% in Y-direction for Wind analysis, 20.71% in X-direction and 23.81% in Y-direction for Gust Factor analysis by providing outrigger at top and 0.4H i.e. height of the building.
3. In parameter study of Storey Drift it is reduced by 21.51% in X-direction and 16.61% in Y-direction for Equivalent Static analysis, 18.46% in X-direction and 11.73% in Y-direction for Response Spectrum analysis, 15.11% in X-direction and 9.65% in Y-direction for Wind analysis, 14.80% in X-direction and 17.34% in Y-direction for Gust Factor analysis by providing outrigger at top and 0.4H i.e. height of the building.
4. In parametric study of base shear there is no significant difference in base shear values for equivalent static analysis, wind analysis and Gust Factor analysis. But for Response Spectrum analysis base shear value considerably decreases due to variable mass at different floors and Equivalent static analysis wind analysis and Gust Factor analysis fails to catch the same.
5. By introducing outrigger structural system, the time period can be controlled considerably. In parametric study there is maximum reduction in time period when outriggers are placed at top and 0.4H i.e. height of the building.
6. In parametric study of Base moments and Torsion there is no significant difference in values of base moments and torsion for equivalent static analysis, wind analysis and Gust Factor analysis. But for Response Spectrum analysis base moment and torsion value considerably decreases.
7. For different outrigger configurations, base shear does not affect to great extent.
8. When buildings are in geometrically irregular shape we cannot just rely on equivalent static analysis and hence it is essential to perform dynamic analysis due to nonlinear distribution of forces.
9. Thus, conclusion is drawn that optimum location of outriggers is top and 0.4H i.e. height of the building.

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